28p-A7-2

Spin Seebeck Thermoelectric Generators

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The ever increasing waste of energy in the form of heat dissipated into the environment is an important part of the global energy crisis. In principle, this heat can, even at moderate temperature, be harvested by thermoelectric devices based on the Seebeck effect. The efficiency of a thermoelectric generator based on the conventional Seebeck effect can be represented by the dimensionless figure of merit $ZT=S^2TG/K$, where S is the Seebeck coefficient, T is the temperature, G is the electric conductivity, and K is the heat conductivity [1]. Unfortunately, ZT at room temperature could not be increased significantly above unity in recent decades. This value corresponds to less than 20% of the Carnot efficiency which is not sufficient to compete with conventional power generators.

Recently, it was discovered that a temperature gradient in a ferromagnetic insulators creates a spin current in an adjacent non-magnetic metal [2]. The spin-orbit interaction in this non-magnetic metal transforms the spin current into a transverse charge current by the inverse spin Hall effect (ISHE). The combination of thermal spin injection by the collective excitations of the magnetic order parameter and the ISHE is now referred to as spin Seebeck effect (SSE). The SSE might be attractive for large area thermoelectric power generation [3]. However, since the physical mechanism of the SSE is very different from the conventional Seebeck effect, the conventional definition for the figure of merit fails.

We model thermoelectric power generators based on the SSE and find that the figure of merit is proportional to the product of resistivity times spin-flip length of the metal, which offers a convenient way to improve efficiency. However, a quadratic dependence on the spin Hall angle strongly suppresses the efficiency for most materials.

We therefore propose an alternative method to generate energy from thermally generated spin currents by using a spin filter made by a ferromagnetic metal instead of ISHE, which will be shown to perform better in micro and nanostructures.

References

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